

**CLAIMS**

1. A zoom lens consisting of a first lens group having positive refracting power, a second lens group having  
5 negative refracting power, a third lens group having positive refracting power, and a fourth lens group having positive refracting power, which are disposed in order from an object side, wherein the first lens group and the third lens groups are stationary, and the zoom lens  
10 performs mainly variable power by shifting the second lens group in an optical axis direction, and performs correction for image position fluctuations and focusing by shifting the fourth lens group in the optical axis direction, characterized in that:

15 said first lens group is composed of five lenses: a concave lens; a convex lens with a strong convexity facing to an image side; a cemented lens composed of a concave lens with a strong concavity facing to the image side, and a convex lens; and a convex lens with a strong  
20 convexity facing to the object side, which are disposed in order from the object side, and is configured so as to satisfy each of the following conditional expressions:

- (1)  $1.25 < h_{1-1}/h_{1-4} < 1.55$ ;  
(2)  $d_{1-2}/d_{1-3} < 0.4$ ;  
25 (3)  $1.65 < n_{1-2}$ ; and  
(4)  $0.1 < H_{1'}/f_1 < 0.6$ ,

where:

$f_1$  is a focal length of the first lens group;  
 $h_{1-i}$  is a paraxial ray height in the  $i$ -th surface  
30 from the object side when allowing a paraxial ray parallel to an optical axis to enter the first lens

group;

$d_{1-i}$  is axial spacing from the  $i$ -th surface to the  $(i+1)$ -th surface in the first lens group;

$n_{1-i}$  is a refractive index on a d-line of the  $i$ -th  
5 lens in the first lens group; and

$H_{1'}$  is spacing from a vertex of a surface closest to the image side in the first lens group to a principal point on the image side in the first lens group ("-" indicates the object side, and "+" indicates the image  
10 side).

2. The zoom lens as claimed in Claim 1,

characterized in that the second lens group is composed of three lenses of a concave meniscus lens with  
15 a concavity facing to the image side, a double concave lens and a convex lens, which are disposed in order from the object side, and

characterized by satisfying the following conditional expression (5):

20 (5)  $1.8 < (n_{2-1} + n_{2-2})/2$ ,

where:

$n_{2-1}$  is a refractive index on a d-line of the concave meniscus lens of the second lens group; and

$n_{2-2}$  is a refractive index on a d-line of the  
25 double concave lens of the second lens group.

3. The zoom lens as claimed in Claim 1,

characterized in that:

the third lens group is composed of a single  
30 convex lens, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a cemented lens made up of a concave meniscus lens with a concavity facing to the image side, and a double convex lens whose surface on the image side is an aspheric surface, which are disposed in order from the object side, and

characterized by satisfying each of the following conditional expressions (6), (7), and (8):

(6)  $-0.4 < f_3/r_{3-2} < 0.4$ ;

10 (7)  $-1.25 < r_{4-1}/r_{4-3} < -0.8$ ; and

(8)  $0.3 < r_{4-2}/f_4 < 0.6$ ,

where:

$f_3$  is a focal length of the third lens group;

$f_4$  is a focal length of the fourth lens group;

15  $r_{3-2}$  is a radius of curvature of the image side surface of the convex lens of the third lens group;

$r_{4-1}$  is a radius of curvature of the object side surface of the concave meniscus lens of the fourth lens group;

20  $r_{4-2}$  is a radius of curvature of a cemented surface of the fourth lens group; and

$r_{4-3}$  is a radius of curvature of a surface on the image side of the convex lens of the fourth lens group.

25 4. The zoom lens as claimed in Claim 2, characterized in that:

the third lens group is composed of a single convex lens, and at least one surface is an aspheric surface; and

30 the fourth lens group is composed of a cemented lens made up of a concave meniscus lens with a

concavity facing to the image side, and a double convex lens whose surface on the image side is an aspheric surface, which are disposed in order from the object side, and

5 characterized by satisfying each of the following conditional expressions (6), (7), and (8):

$$(6) \quad -0.4 < f_3/r_{3-2} < 0.4;$$

$$(7) \quad -1.25 < r_{4-1}/r_{4-3} < -0.8; \text{ and}$$

$$(8) \quad 0.3 < r_{4-2}/f_4 < 0.6,$$

10 where:

$f_3$  is a focal length of the third lens group;

$f_4$  is a focal length of the fourth lens group;

$r_{3-2}$  is a radius of curvature of the image side surface of the convex lens of the third lens group;

15  $r_{4-1}$  is a radius of curvature of the object side surface of the concave meniscus lens of the fourth lens group;

$r_{4-2}$  is a radius of curvature of a cemented surface of the fourth lens group; and

20  $r_{4-3}$  is a radius of curvature of a surface on the image side of the convex lens of the fourth lens group.

5. The zoom lens as claimed in Claim 1, characterized in that:

25 the third lens group is composed of a convex lens, and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave lens with a strong concavity facing to an image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

30 the fourth lens group is composed of a single

convex lens, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9) and (10):

5           (9)  $0.4 < h_{3-5}/h_{3-1} < 0.7$ ; and

          (10)  $0.75 < f_3/f_{3-1} < 1$ ,

where:

$h_{3-i}$  is a paraxial ray height in the  $i$ -th surface from the object side of the third lens group, when  
10   allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

$f_3$  is a focal length of the third lens group; and

$f_{3-1}$  is a focal length of the single convex lens of the third lens group.

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6.   The zoom lens as claimed in Claim 2,  
characterized in that:

          the third lens group is composed of a convex lens, and a cemented lens made up of a convex lens with a  
20   strong convexity facing to an object side and a concave lens with a strong concavity facing to an image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

          the fourth lens group is composed of a single  
25   convex lens, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9) and (10):

          (9)  $0.4 < h_{3-5}/h_{3-1} < 0.7$ ; and

30           (10)  $0.75 < f_3/f_{3-1} < 1$ ,

where:

h3-i is a paraxial ray height in the i-th surface from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

5        f3 is a focal length of the third lens group; and

      f3-1 is a focal length of the single convex lens of the third lens group.

7. The zoom lens as claimed in Claim 1,

10        characterized in that:

      the third lens group is composed of a single convex lens, and at least one surface is an aspheric surface; and

      the fourth lens group is composed of a  
15        cemented lens made up of a convex lens with a convexity facing to the object side, a concave lens, and a convex lens, which are disposed in order from the object side, and at least a surface closest to the object side is an aspheric surface, and

20        characterized by satisfying each of the following conditional expressions (11) and (12):

      (11)  $n_{4-2} > 1.8$ ; and

      (12)  $0.1 < f_3/f_4 < 0.7$ ,

where:

25         $n_{4-2}$  is a refractive index on a d-line of the concave lens of the fourth lens group;

      f3 is a focal length of the third lens group; and

      f4 is a focal length of the fourth lens group.

30        8. The zoom lens as claimed in Claim 2,

      characterized in that:

the third lens group is composed of a single convex lens, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a  
5 cemented lens made up of a convex lens with a convexity facing to the object side, a concave lens, and a convex lens, which are disposed in order from the object side, and at least a surface closest to the object side is an aspheric surface, and

10 characterized by satisfying each of the following conditional expressions (11) and (12):

(11)  $n_{4-2} > 1.8$ ; and

(12)  $0.1 < f_3/f_4 < 0.7$ ,

where:

15  $n_{4-2}$  is a refractive index on a d-line of the concave lens of the fourth lens group;

$f_3$  is a focal length of the third lens group; and

$f_4$  is a focal length of the fourth lens group.

20 9. The zoom lens as claimed in Claim 1,  
characterized in that:

the third lens group is composed of a convex lens and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave  
25 lens with a strong concavity facing to the image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

the fourth lens group is composed of a  
cemented lens made up of a double convex lens and a  
30 concave lens with a convexity facing to the image side, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9), (11), and (13):

$$(9) \quad 0.4 < h_{3-5}/h_{3-1} < 0.7;$$

$$(11) \quad n_{4-2} > 1.8; \text{ and}$$

$$5 \quad (13) \quad 0.75 < f_3/f_{3-1} < 1.3,$$

where:

$h_{3-i}$  is a paraxial ray height in the  $i$ -th surface from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to  
10 enter the first lens group at a wide angle end;

$f_3$  is a focal length of the third lens group;

$f_{3-1}$  is a focal length of the single convex lens of the third lens group; and

$n_{4-2}$  is a refractive index on a d-line of the  
15 concave lens of the fourth lens group.

10. The zoom lens as claimed in Claim 2,  
characterized in that:

the third lens group is composed of a convex  
20 lens and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave lens with a strong concavity facing to the image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

25 the fourth lens group is composed of a cemented lens made up of a double convex lens and a concave lens with a convexity facing to the image side, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following  
30 conditional expressions (9), (11), and (13):

$$(9) \quad 0.4 < h_{3-5}/h_{3-1} < 0.7;$$



(11)  $n_{4-2} > 1.8$ ; and

(13)  $0.75 < f_3/f_{3-1} < 1.3$

where:

$h_{3-i}$  is a paraxial ray height in the  $i$ -th surface  
5 from the object side of the third lens group, when  
allowing a paraxial ray parallel to an optical axis to  
enter the first lens group at a wide angle end;

$f_3$  is a focal length of the third lens group;

$f_{3-1}$  is a focal length of the single convex lens of  
10 the third lens group; and

$n_{4-2}$  is a refractive index on a d-line of the  
concave lens of the fourth lens group.

11. An image pickup apparatus including: a zoom lens;  
15 image pickup means for converting an image captured by  
the zoom lens into an electric image signal; and image  
control means, characterized in that:

said image control means is configured so as to  
form a new image signal subjected to coordinate  
20 conversion by shifting a point on an image defined by an  
image signal formed by said image pickup means, while  
referring to a conversion coordinate factor previously  
provided in response to a variable power rate through  
said zoom lens, and output the new image signal;

25 said zoom lens is composed of a first lens group  
having positive refracting power, a second lens group  
having negative refracting power, a third lens group  
having positive refracting power, and a fourth lens group  
having positive refracting power, which are disposed in  
30 order from the object side, in which the first lens group  
and the third lens group are stationary, and the zoom

lens performs mainly variable power by shifting the second lens group in an optical axis direction, and performs correction for image position fluctuations and focusing by shifting the fourth lens group in the optical axis direction; and

said first lens group is composed of five lenses: a concave lens; a convex lens with a strong convexity facing to an image side; a cemented lens made up of a concave lens with a strong concavity facing to the image side, and a convex lens; and a convex lens with a strong convexity facing to the object side, which are disposed in order from the object side, and is characterized by satisfying each of the following conditional expressions:

(1)  $1.25 < h1-1/h1-4 < 1.55$ ;

(2)  $1-2/d1-3 < 0.4$ ;

(3)  $1.65 < n1-2$ ; and

(4)  $0.1 < H1'/f1 < 0.6$ ,

where:

$f1$  is a focal length of the first lens group;

$h1-i$  is a paraxial ray height in the  $i$ -th surface from the object side when allowing a paraxial ray parallel to an optical axis to enter the first lens group;

$d1-i$  is axial spacing from the  $i$ -th surface to the  $(i+1)$ -th surface in the first lens group;

$n1-i$  is a refractive index on a d-line of the  $i$ -th lens in the first lens group; and

$H1'$  is spacing from a vertex of a surface closest to the image side in the first lens group to a principal point on the image side in the first lens group ("-" indicates the object side, and "+" indicates the image

side).

12. The image pickup apparatus as claimed in Claim 11, characterized in that:

5       the second lens group of said zoom lens is composed of three lenses of a concave meniscus lens with a strong concavity facing to the image side, a double concave lens, and a convex lens, which are disposed in order from the object side, and satisfies the following conditional expression (5):

10       expression (5):

$$(5) \quad 1.8 < (n2-1+n2-2)/2,$$

where:

      n2-1 is a refractive index on a d-line of the concave meniscus lens of the second lens group; and

15       n2-2 is a refractive index on a d-line of the double concave lens of the second lens group.

13. The image pickup apparatus as claimed in Claim 11, characterized in that:

20       the third lens group of said zoom lens is composed of a single convex lens, and at least one surface is an aspheric surface; and

      the fourth lens group of said zoom lens is composed of a cemented lens made up of a concave meniscus lens with a concavity facing to the image side, and a double convex lens whose surface on the image side is an aspheric surface, which are disposed in order from the object side, and

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      characterized by satisfying each of the following conditional expressions (6), (7), and (8):

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$$(6) \quad -0.4 < f3/r3-2 < 0.4;$$

(7)  $-1.25 < r_{4-1}/r_{4-3} < -0.8$ ; and

(8)  $0.3 < r_{4-2}/f_4 < 0.6$ ,

where:

$f_3$  is a focal length of the third lens group;

5  $f_4$  is a focal length of the fourth lens group;

$r_{3-2}$  is a radius of curvature of the image side surface of the convex lens of the third lens group;

$r_{4-1}$  is a radius of curvature of the object side surface of the concave meniscus lens of the fourth lens group;

10  $r_{4-2}$  is a radius of curvature of a cemented surface of the fourth lens group; and

$r_{4-3}$  is a radius of curvature of a surface on the image side of the convex lens of the fourth lens group.

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14. The image pickup apparatus as claimed in Claim 12, characterized in that:

the third lens group of said zoom lens is composed of a single convex lens, and at least one surface is an aspheric surface; and

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the fourth lens group of said zoom lens is composed of a cemented lens made up of a concave meniscus lens with a concavity facing to the image side, and a double convex lens whose surface on the image side is an aspheric surface, which are disposed in order from the object side, and

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characterized by satisfying each of the following conditional expressions (6), (7), and (8):

(6)  $-0.4 < f_3/r_{3-2} < 0.4$ ;

30

(7)  $-1.25 < r_{4-1}/r_{4-3} < -0.8$ ; and

(8)  $0.3 < r_{4-2}/f_4 < 0.6$ ,

where:

f3 is a focal length of the third lens group;

f4 is a focal length of the fourth lens group;

5 r3-2 is a radius of curvature of the image side  
surface of the convex lens of the third lens group;

r4-1 is a radius of curvature of the object side  
surface of the concave meniscus lens of the fourth lens  
group;

10 r4-2 is a radius of curvature of a cemented surface  
of the fourth lens group; and

r4-3 is a radius of curvature of a surface on the  
image side of the convex lens of the fourth lens group.

15 15. The image pickup apparatus as claimed in Claim 11,  
characterized in that:

the third lens group of said zoom lens is  
composed of a convex lens, and a cemented lens made up of  
a convex lens with a strong convexity facing to the  
object side, and a concave lens with a strong concavity  
20 facing to an image side, which are disposed in order from  
the object side, and at least one surface is an aspheric  
surface; and

the fourth lens group of said zoom lens is  
composed of a single convex lens, and at least one  
25 surface is an aspheric surface, and

characterized by satisfying each of the following  
conditional expressions (9) and (10):

(9)  $0.4 < h_{3-5}/h_{3-1} < 0.7$ ; and

(10)  $0.75 < f_3/f_{3-1} < 1$ ,

30 where:

h3-i is a paraxial ray height in the i-th surface

from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group; and

5 f3-1 is a focal length of the single convex lens of the third lens group.

16. The image pickup apparatus as claimed in Claim 12, characterized in that:

10 the third lens group of said zoom lens is composed of a convex lens, and a cemented lens made up of a convex lens with a strong convexity facing to the object side, and a concave lens with a strong concavity facing to an image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

the fourth lens group of said zoom lens is composed of a single convex lens, and at least one surface is an aspheric surface, and

20 characterized by satisfying each of the following conditional expressions (9) and (10):

(9)  $0.4 < h_{3-5}/h_{3-1} < 0.7$ ; and

(10)  $0.75 < f_3/f_{3-1} < 1$ ,

wherein:

25 h3-i is a paraxial ray height in the i-th surface from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group; and

30 f3-1 is a focal length of the single convex lens of the third lens group.

17. The image pickup apparatus as claimed in Claim 11,  
characterized in that:

the third lens group of said zoom lens is  
5 composed of a single convex lens, and at least one  
surface is an aspheric surface; and

the fourth lens group of said zoom lens is  
composed of a cemented lens made up of a convex lens with  
a convexity facing to an object side, a concave lens, and  
10 a convex lens, which are disposed in order from the  
object side, and at least a surface closest to the object  
side is an aspheric surface, and

characterized by satisfying each of the following  
conditional expressions (11) and (12):

15 (11)  $n_{4-2} > 1.8$ ; and  
(12)  $0.1 < f_3/f_4 < 0.7$ ,

where:

$n_{4-2}$  is a refractive index on a d-line of the  
concave lens of the fourth lens group;

20  $f_3$  is a focal length of the third lens group; and  
 $f_4$  is a focal length of the fourth lens group.

18. The image pickup apparatus as claimed in Claim 12,  
characterized in that:

25 the third lens group of said zoom lens is  
composed of a single convex lens, and at least one  
surface is an aspheric surface; and

the fourth lens group of said zoom lens is  
composed of a cemented lens made up of a convex lens with  
30 a convexity facing to an object side, a concave lens, and  
a convex lens, which are disposed in order from the

object side, and at least a surface closest to the object side is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (11) and (12):

- 5           (11)  $n_{4-2} > 1.8$ ; and  
            (12)  $0.1 < f_3/f_4 < 0.7$ ,

where:

$n_{4-2}$  is a refractive index on a d-line of the concave lens of the fourth lens group;

- 10            $f_3$  is a focal length of the third lens group; and  
             $f_4$  is a focal length of the fourth lens group.

19. The image pickup apparatus as claimed in Claim 11, characterized in that:

- 15           the third lens group of said zoom lens is composed of a convex lens and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave lens with a strong concavity facing to the image side, which are disposed in order  
20 from the object side, and at least one surface is an aspheric surface; and

- the fourth lens group of said zoom lens is composed of a cemented lens made up of a double convex lens and a concave lens with a convexity facing to the  
25 image side, and at least one surface is an aspheric surface, and

characterized by satisfying each of the following conditional expressions (9), (11), and (13):

- (9)  $0.4 < h_{3-5}/h_{3-1} < 0.7$ ;  
30           (11)  $n_{4-2} > 1.8$ ; and  
            (13)  $0.75 < f_3/f_{3-1} < 1.3$ ,



where:

h3-i is a paraxial ray height in the i-th surface from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

f3 is a focal length of the third lens group;

f3-1 is a focal length of the single convex lens of the third lens group; and

n4-2 is a refractive index on a d-line of the concave lens of the fourth lens group.

20. The image pickup apparatus according to claim 12, characterized in that:

the third lens group of said zoom lens is composed of a convex lens and a cemented lens made up of a convex lens with a strong convexity facing to the object side and a concave lens with a strong concavity facing to the image side, which are disposed in order from the object side, and at least one surface is an aspheric surface; and

the fourth lens group of said zoom lens is composed of a cemented lens made up of a double convex lens and a concave lens with a convexity facing to the image side, and at least one surface is an aspheric surface, characterized by satisfying each of the following conditional expressions (9), (11), and (13):

$$(9) \quad 0.4 < h3-5/h3-1 < 0.7;$$

$$(11) \quad n4-2 > 1.8; \text{ and}$$

$$(13) \quad 0.75 < f3/f3-1 < 1.3,$$

where:

h3-i is a paraxial ray height in the i-th surface

from the object side of the third lens group, when allowing a paraxial ray parallel to an optical axis to enter the first lens group at a wide angle end;

$f_3$  is a focal length of the third lens group;

5         $f_{3-1}$  is a focal length of the single convex lens of the third lens group; and

$n_{4-2}$  is a refractive index on a d-line of the concave lens of the fourth lens group.